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SHORT COMMUNICATION

Distribution of Fish in the Upper Citarum River: an Adaptive Response to Physico-Chemical Properties

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Distribution of fish in river is controlled by physico-chemical properties of the water which is affected by land-use complexity and intensity of human intervention. A study on fish distribution was carried out in the upper Citarum River to map the effects of physio-chemical properties on habitat use. A survey was conducted to collect fish and to measure the water quality both on dry and rainy season. The result showed that distribution of the fish, in general, represented their adaptive response to physico-chemical properties. The river environment could be grouped into two categories: (i) clean and relatively unpolluted sites, which associated with high DO and water current, and (ii) polluted sites characterized by low DO, high COD, BOD, water temperature, NO_3, PO_4, H_2S, NH_3, and surfactant. Fish inhabiting the first sites were *Xiphophorus helleri*, *Punctius binotatus*, *Xiphophorus maculatus*, and *Oreochromis mossambicus*. Meanwhile, the latter sites were inhabited by *Liposarcus pardalis*, *Trichogaster trichopterus*, and *Poecilia reticulata*. Knowledge about fish distribution in association with the pysico-chemical properties of water is crucial especially for the river management.

Key words: fish, distribution, physico-chemical properties, Citarum River

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INTRODUCTION

Habitat selection in fish community has been a big concern of fish ecologists. Knowledge on this matter is critical because of its significance, mainly in the efforts of riverine resource management and conservation. Research on habitat selection in fish, both in lenthic and lothic ecosystems, is abundant. Fish ecologists have identified numerous determining factors which play important role in their distribution along the habitat, either horizontally or longitudinally. Habitat selection in fish can be a consequence of its bio-ecological characteristics, as internal factor, or a resultance of their interactions with environmental variables, as external factors. For the first factor, diversification in anatomy and morphology, physiology, and interspecific behavior have been considered as the initial step in development and evolution of resource polymorphisme (Wimberger 1994; Skúlason & Smith 1995; McLaughlin *et al*. 1999), including habitat types. While for the second factor, presence of predator (Sunardi *et al*. 2005), limitation in resources (Menge & Sutherland 1987), and physico-chemical properties of water are considered to be important factors. Variation in habitat use, in turn expose the animals to diverse and selective environmental pressures which may facilitate changes in development and evolution in physiology and morphology.

Physico-chemical conditions of river have been reported to affect habitat use in fish (Whiteside & McNatt 1972; Hughes & Gammon 1987; Herbert & Gelwick 2003). Physico-chemical properties of water in lothic habitat and its influences on community are determined by a number of environmental variables, such as climate, landscape, and effluent of wastewater. In fact, the presence of fish in a space is a function of pressures of environmental factors, and this adaptation is as a function of, and a cause of, specific habitat preference. Therefore, fish distribution along a longitudinal gradient of a river can be considered as an adaptive response to phyco-chemical properties of the water.

A river which flows through urban areas commonly experiences serious water pollution. Like the Citarum River, which is facing a decreased water quality caused by pollution (Parikesit *et al*. 2005), resulting an extreme difference between upstream and downstream, proportional to material input from the surrounding environment.

Study of spatial use in fish community is very useful mainly to understand the population dynamics and community processes. This study was carried out to map the distribution of fish species in the upper part of Citarum River, as well as to evaluate the corresponding environmental factors which is important for river management.

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MATERIALS AND METHODS

Study Site. This study was carried out in the upper Citarum River which encompasses the water spring at Mount Wayang to the river mouth at Saguling Reservoir, West Java Province (Figure 1). Eleven sampling sites were established during preliminary survey to cover the major types of land-uses, and based on accessibility. The upper most area is natural forest vegetation of Mount Wayang, and tea plantation. At the lower part, the land-use is dominated by vegetable garden and village settlements. Dense settlement and paddy field are found in more downstream sites. The lower most part is an urban area where many industries locate.

Sampling Protocols. Both fish and water sampling were carried out twice during the study, i.e. both on rainy and dry season. First step of this sampling activity was to invent fish species by enlisting all species captured, including both indigenous and introduced species. Fishing was done using a cast net with opening of 2.5 m and 1.0 cm^2 mesh-size. Fishing was performed by throwing the cast net for about fifty times at each sampling site where movement of fish collections was made against the river flow. For sites where this technique was unable to perform, electric fishing device or fish net was used in the sampling.

Captured fish were identified on site; number of species and number of individuals were recorded for population estimation. Fish identification refers to Kotellat and Whitten (1993). In addition, total weight and total body length were also measured to determine the characteristics of each species. Population was estimated using following formulae: Catch per Unit Effort (*CpUE*) i.e. number of fish captured/number of effort. When the number of fish captured was too small, population was estimated per total effort. Fish were then collected for advanced identification purpose.

Water samples were taken using water sampler or water dipper, and then put into polyethylene/glass containers. Water temperature, pH, DO, HCO^{3-}, and CO_2 were measured on site. While TDS, BOD, COD, H_2S, NH_3, NO_3-N, PO_4-P, and surfactant, were measured in the laboratory. Analysis of all parameters refers to APHA (1995). Width, depth and water velocity of the river were also measured to provide complete information about the sampling location.

Vicinity of sampling sites was also described to anticipate a phenomenon or condition, even small thing that might have a considerable effect on water quality in sampling location. Such description covered, for example, land use, dominant riparian vegetation, tributary, factory, garbage and so on.

Analysis. Fish community and physico-chemical parameters of the water were analyzed to investigate the fish distribution against environmental gradients. The analysis was performed using ordination technique. Canonical Correspondence Analysis (CCA) is an ordination method which correlates variation in species composition to environmental factors, thus showing relationship between the species and the environmental factors on the study site. This cluster analysis was carried out using PC-ORD which results ordination and similarity between the sampling sites.

RESULTS

Fish Species of Upper Citarum River. Ten species were found in the upper Citarum River during the study period. In rainy season, 8 species were found with total number of capture 64 fish. In dry season, 44 fish belonged to 9 species were collected. Species found during both sampling occasions were minnows (*Punctius binotatus:* Cyprinidae), walking catfish (*Clarias gariepinus:* Clariidae), impun paris (*Xiphophorus helleri:* Poeciliidae), impun (*Poecilia reticulata:* Poeciliidae), keting (*Mystus microcanthus:* Bagridae), cichlids (*Oreochromis mossambicus:* Cichlidae), Suckermouth catfish (*Liposarcus pardalis:* Loriicaridae), sepat (*Trichogaster tricopterus:* Belontiidae), common carp (*Cyprinus carpio:* Cyprinidae), betok (*Anabas testudinus:* Anabantidae), and impun paris beureum (*Xiphophorus maculatus:* Poeciliidae) (Table 1 & 2).

Number of species from both sampling occasions was not markedly different, as well as the number of fish. However, in dry season there were two species found which were not captured in the previous sampling occasion (rainy season). Those were *A. testudinus* and *X. maculatus*. On the contrary, a species i.e. *M. microcanthus*, was found in rainy season which was not found during the latter sampling occasion. Generally, the most abundant species found in the upper Citarum River were *L. pardalis*, *T. trichopterus*, *P. reticulata*, and *P. binotatus* which spread to different locations.

Fish Distribution. The cluster analysis shows that site 7 and 8 of rainy season has similar (100%) fish species, and these sites were correlated with site 6 (90%). Site 1 of

Table 1. Spesies and number of fish captured in Citarum River in rainy season

Spesies	Localities										
	1	2	3	4	5	6	7	8	9	10	11
Punctius binotatus (Cyprinidae)	4	2	-	-	-	-	-	-	-	-	-
Clarias gariepinus (Clariidae)	-	1	-	-	-	-	1	-	-	-	-
Xiphophorus helleri (Poeciliidae)	7	-	-	-	-	-	-	-	-	-	-
Poecilia reticulata (Poeciliidae)	1	-	-	-	-	-	-	-	-	-	-
Mystus microcanthus (Bagridae)	-	-	1	-	-	-	-	-	-	-	-
Oreochromis mossambicus (Cichlidae)	-	-	1	-	-	-	-	-	1	-	1
Liposarcus pardalis (Loriicaridae)	-	-	-	11	-	4	5	-	-	-	9
Trichogaster trichopterus (Belontiidae)	-	-	-	-	-	-	-	1	1	-	13
Total	12	3	2	11	0	4	6	1	2	0	23

Table 2. Spesies and number of fishes captured in Citarum River in dry season

Spesies	Localities										
	1	2	3	4	5	6	7	8	9	10	11
Anabas testudinus (Anabantidae)	-	-	-	-	4	-	-	-	-	-	-
Punctius binotatus (Cyprinidae)	1	-	-	-	-	-	-	-	-	-	-
Xiphophorus helleri (Poeciliidae)	-	-	1	-	-	-	-	-	-	-	-
Poecilia reticulata (Poeciliidaae)	18	-	-	-	-	-	-	-	-	-	-
Xiphophorus maculatus (Poecliidae)	6	-	-	-	-	-	-	-	-	-	-
Cyprinus carpio (Cyprinidae)	2	-	1	-	-	-	-	-	-	-	-
Oreochromis mossambicus (Cichlidae)	-	-	2	-	-	-	-	-	-	-	-
Liposarcus pardalis (Loriicaridae)	-	-	-	7	-	1	-	-	-	-	-
Trichogaster trichopterus (Belontiidae)	-	-	-	-	-	-	-	-	-	-	1
Total	27	0	4	7	4	1	0	0	0	0	1

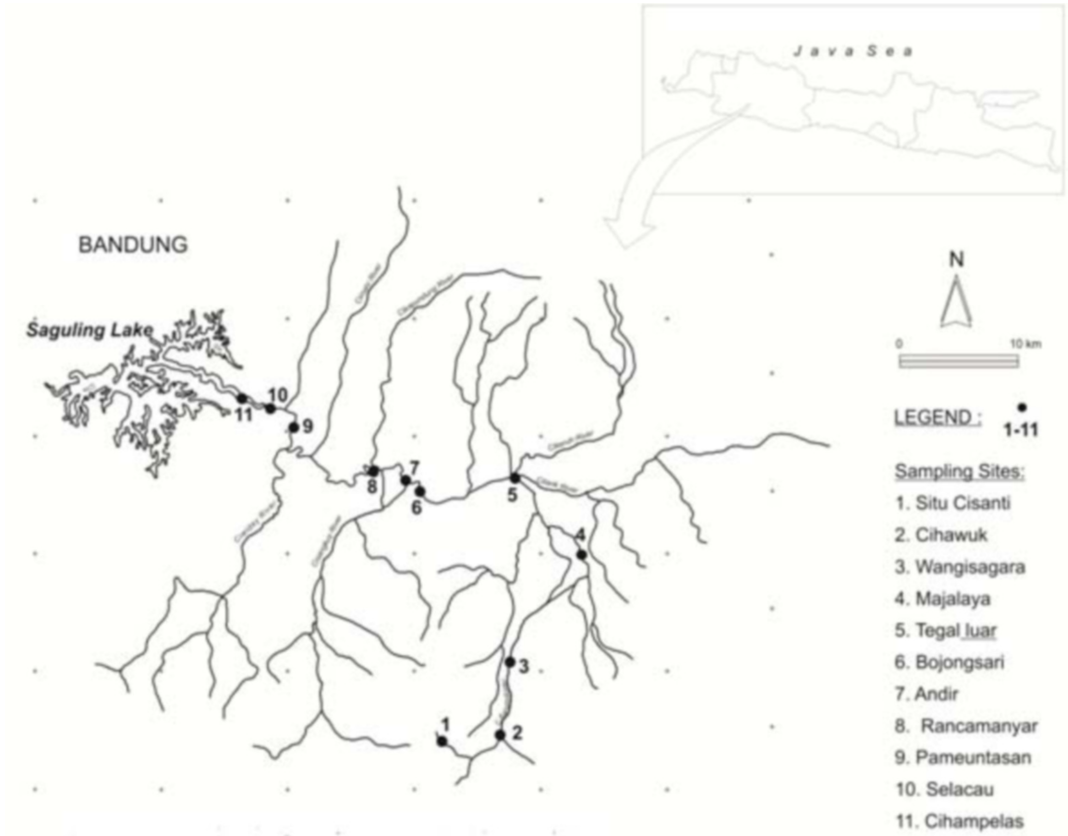

Figure 1. Sampling sites at the upper Citarum River.

rainy season and dry season were highly similar (98%). Other sites that showed high species similarity were site 9 and site 11 of rainy season (95%), and site 2 and 3 of dry season (85%) (Figure 2).

There were two different conditions recognized in Citarum River as identified by the CCA; those were (i) locations with poor water quality as indicated by the presence of contaminants and pollutants, and generally associated with relatively higher water temperature. High value of TDS, BOD, and COD were characteristics in these locations. In addition, nutrient (NO_3 and PO_4), NH_3 and H_2S also appeared in a considerable amount. Such locations were site 6, 7, and 11 which located at the lower part of the river course; and (ii) locations characterized by high DO concentration and high water current, and seemed to have a good water quality as indicated by low concentration of pollution parameters. Such locations were site 2 and site 3 in the upstream area (Figure 3).

Due to its habitat characteristics, fish community was divided into two groups, i.e., species which inhabited the unpolluted water (such as *X. Helleri*, *P. binotatus*, *X. maculatus*, and *O. mossambicus*); and species which survived in poor water quality (such as *L. pardalis*, *T. trichopterus*, and *P. reticulata*). Some species were found in moderate water quality such as *C. carpio* and *A. testudinus* (Figure 3).

DISCUSSION

Land use along Citarum river basin is very diverse, and comprises of natural, semi-natural and non-natural ecosystems. Complexity of physical and non-physical characteristics of a watershed determines the physico-chemical properties of the water, biological community and ecological integrity of the river. Intensive human intervention in the landscape has caused decrease in

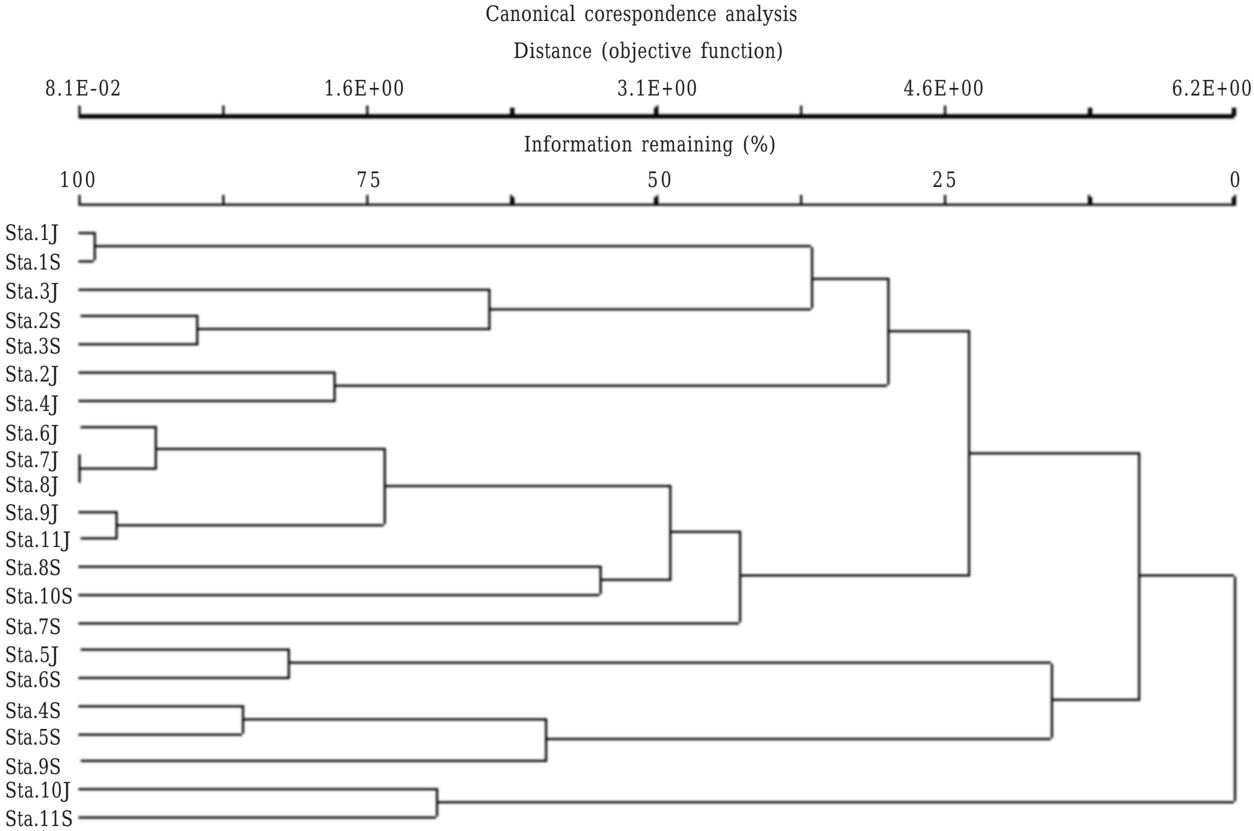

Figure 2. Cluster analysis of fish sample collected during Rainy and Dry season. *Sta* denotes sampling station, whereas numbers show order of sampling site. J and S denote period of sampling, Rainy and Dry season, respectively.

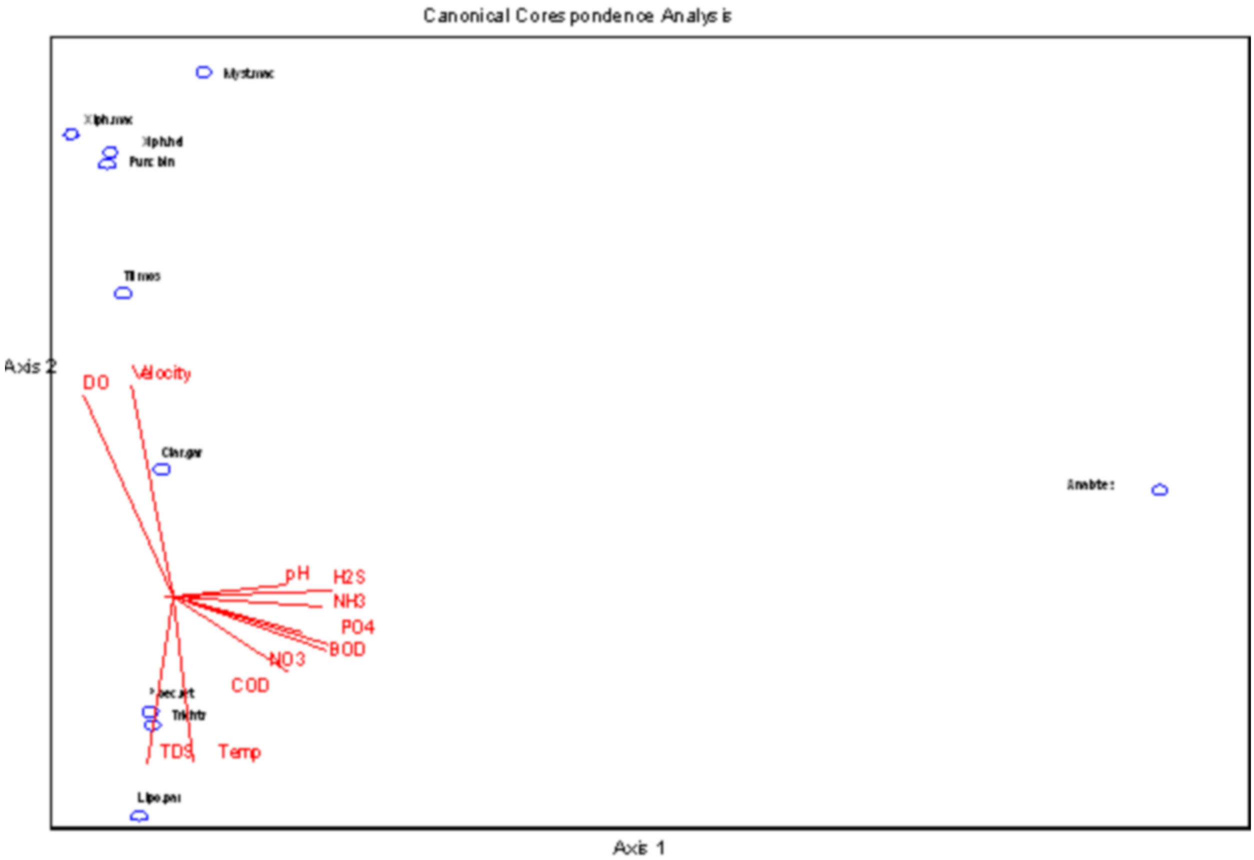

Figure 3. Biplot diagram showing the relation between fish species and physic-chemical properties of water quality.

natural ecosystems, which in turn degrading most of the river habitats available for biota. This study demonstrated that land use complexity has created different microhabitats inside the river. Such pressure has evolved into a force which determines and controls the presence and diversity of biological organisms including fish, macroinvertebrates, and algae (Jones 2001).

Microhabitat variation of the river can be clearly defined based on the physico-chemical properties of water; materials input from the surrounding area have created changes in physical and chemical environment of the river. The result of this study indicated that the water quality tend to degrade along with complexity of the land use. Generally, parameters of contamination indicators increased at the lower parts of the river course. Previous study demonstrated that the upper Citarum River suffered from heavy pollution due to various human activities such as farming, animal husbandry and textile industries (Parikesit *et al*. 2005).

Fish population in the upper Citarum River has decreased along with river gradient. Increase in pollutant load and habitat destruction, such as lost of riparian vegetation, is the cause of this phenomenon. The river continuum concept states that the biodiversity increases along with the increase in river order; such pattern is caused by the increase in habitat complexity in downstream area (Vinson & Hawkins 1998), particularly in food resources. However, human pressures have suppressed the opportunity of the biotic existence, including fish. In fact, the lower parts of the river course of the river contains fewer species and smaller population. The fish populations deplete, indicating habitat degradation and decrease in ecological integrity of the Citarum River. Poor water quality and degradation of natural habitats may cause extinction of the sensitive taxa from the ecosystem. Typical responses of aquatic organisms assemblages include reduced richness and diversity, and increased abundances of tolerant organisms in urbanized streams (Haffner *et al*. 1994; Roy *et al*. 2003; Cuffney *et al*. 2005). Likewise, fish responses to urbanization include reduced biotic integrity (Morgan & Cushman 2005) and increased homogenization of assemblages (Marchetti *et al*. 2006; Scott 2006). Allan (2004) pointed out that there are several mechanisms by which land use change alters stream biota, including: riparian clearing and loss of large wood, hydrologic alteration, excessive sedimentation, nutrient enrichment, and contaminant pollution.

The complex environmental and human pressures have divided river ecosystem into two general conditions i.e., unpolluted- and polluted-habitat. The two different environments result in diversification of its population represent their ecological conditions. The clean and unpolluted sites are occupied by sensitive fish, whereas the polluted sites are populated by tolerant taxa. For the latter group, both unpolluted and polluted sites seem to be favourable due to their adaptation ability. Meanwhile, the fish species living around the spring water or the upper parts of the river course is those are not commonly found in polluted sites. The concentration of DO, in this area, could be the good predictor of "well-being" of the water, where turbulence of water current may sustain the O_2 diffusion from the air. Fish, such as *P. binotatus*, *X. Helleri*, *X. maculatus*, and *M. microcanthus* are recognized as sensitive species.

On the contrary, some species populate the sites where the water quality has *degraded* due to heavy contamination and pollution. Such sites are characterized by high COD and BOD, and low DO concentration, represent load of organic materials. Nitrogen and phosphorus are other indicators for organic pollution originated from domestic and industrial activities. Generation of NH_3 and H_2S from anaerobic respiration, high TDS and relatively higher water temperature are other characteristics of the polluted sites. Laboratory measurement also detected heavy metals; this might be from effluent of the industries which contaminates the water. Species occupy such habitat seem to be able to adapt with poor environmental variable; among others are *L. pardalis*, *T. trichopterus*, and *P. reticulata*. Field observation revealed that *L. pardalis* could survive and succeed to reproduce in the polluted sites. Adaptation ability of fish in such heavily polluted environment may be caused by physiological, behaviour or genetic factor. From the analysis of feeding ecology, food type did not differ significantly among the species. Generally, they are detritus consumers with little variation in their food complement. Based on bio-volume analysis, plankton from different taxa were found in fish stomach with different portion. Among those taxa are Cyanophyta, Bacillariophyceae, Chlorophyta, Euglenophyta and Zooplankton. Cummins (1973) stated that organisms which occupy lotic ecosystem are generalist with wide-overlap of diet between species.

To summarize, fish distribution in Citarum River can be mapped based on physic-chemical properties of the water which is controlled by land use complexity and intensity of human intervention. The upper Citarum River can be classified into two categories i.e., locations with good condition and relatively unpolluted, and locations which are severely damage and polluted. In fact, species distribution represents an adaptive response to physic-chemical properties of water. Information of fish distribution in relation with physic-chemical properties of the water is important for river ecosystem management.

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REFERENCES

Allan JD. 2004. Landscapes and riverscapes: the influence of land use on stream ecosystems. *Annu Rev Ecol Evol Syst* 35:257-284. http://dx.doi.org/10.1146/annurev.ecolsys.35.120202.110122

APHA. 1995. Standard methods for water and wastewater examination. American Public Health Association. Washington, D.C.

Cuffney TF, Zappia H, Giddings EMP, Coles JF. 2005. Effects of urbanization on benthic macroinvertebrate assemblages in contrasting environmental settings: Boston, Massachusetts; Birmingham, Alabama; and Salt Lake City Utah. In: Brown LR, Gray RH, Hughes RM, Meador MM (eds). Effects of Urbaniza-tion on Stream Ecosystems. American Fisheries Society, Bethesda, MD. p 361-408.

Cummins KW. 1973. Trophic relations of aquatic insects. *Ann Rev Entomol* 18:183-206. http://dx.doi.org/10.1146/annurev.en.18.010173.001151

Haffner GD, Tomzaczak M, Lazar R. 1994. Organic contaminant exposure in the Lake St. Clair food web. *Hydrobiologia* 281:19-27. http://dx.doi.org/10.1007/BF00006552

Herbert ME, Gelwick FP. 2003. Spatial variation of headwater fish assemblages explained by hydrologic variability and upstream effects of impoundment. *Copeia* 2:273-284. http://dx.doi.org/10.1643/0045-8511(2003)003[0273:SVOHFA]2.0.CO;2

Hughes RM, Gammon JR. 1987. Longitudinal changes in fish assemblages and water quality in the willamette river, oregon. *T Am Fish Soc* 116:196-209. http://dx.doi.org/10.1577/1548-8659(1987)116<196:LCIFAA>2.0.CO;2

Jones JG. 2001. Freshwater ecosystem–structure and response. *Ecotox Environ Safe* 50:107-113. http://dx.doi.org/10.1006/eesa.2001.2079

Kotellat M, Whitten AJ. 1993. Freshwater fishes of Western Indonesia and Sulawesi. Jakarta: Periplus Editions (HK) Ltd.

Marchetti MP, Lockwood JL, Light T. 2006. Effects of urbanization on California's fishdiversity: differentiation, homogenizationand the influence of spatial scale. *Biol Conserv* 127:310-318. http://dx.doi.org/10.1016/j.biocon.2005.04.025

McLaughlin RL, Ferguson MM, Noakes DLG. 1999. Adaptive peaks and alternative foraging tactics: evidence of short-term divergent selection for sittingand-waiting and actively searching. *Behav Ecol Sociobiol* 45:386-395. http://dx.doi.org/10.1007/s002650050575

Menge BA, Sutherland JP. 1987. Community regulation: variation in disturbance, competition, and predation in relation to environmental stress and recruitment. *Am Nat* 130:730-757. http://dx.doi.org/10.1086/284741

Morgan RP, Cushman SF. 2005. Urbanization effects on stream fish assemblages in Maryland. USA. *J N Am Benthol Soc* 24:643-655. http://dx.doi.org/10.1899/04-019.1

Parikesit, Salim H, Triharyanto E, Gunawan B, Sunardi, Abdoellah OS, Ohtsuka R. 2005. Multi-source water pollution in the Upper Citarum watershed, Indonesia, with special reference to its spatiotemporal variation. *Environ Sci* 12:121-131.

Roy AH, Rosemond AD, Paul MJ, Leigh DS, Wallace JB. 2003. Stream macroinvertebrate response to catchment urbanisation (Geor-gia, USA). *Freshw Biol* 48:329-346. http://dx.doi.org/10.1046/j.1365-2427.2003.00979.x

Scott MC. 2006. Winners and losers among stream fishes in relation to land use legacies and urban development in the southeastern US. *Biol Conserv* 127:301-309. http://dx.doi.org/10.1016/j.biocon.2005.07.020

Skúlason S, Smith TB. 1995. Resource polymorphisms in vertebrates. *Trends Ecol Evol* 10:366-370. http://dx.doi.org/10.1016/S0169-5347(00)89135-1

Sunardi, Asaeda T, Manatunge J. 2005. Foraging of a small planktivore (*Pseudorasbora parva*: Cyprinidae) and its behavioral flexibility in an artificial stream. *Hydrobiologia* 549:155-166. http://dx.doi.org/10.1007/s10750-005-5442-1

Vinson MR, Hawkins CP. 1998. Biodiversity of stream insects: variation at local, basin, and regional scales. *Ann Rev Entomol* 43:271-293. http://dx.doi.org/10.1146/annurev.ento.43.1.271

Whiteside BG, McNatt RM. 1972. Fish species diversity in relation to stream order and physicochemical conditions in the plum creek drainage basin. *Am Midl Nat* 88:90-101. http://dx.doi.org/10.2307/2424490

Wimberger PH. 1994. Trophic polymorphisms, plasticity, and speciation in vertebrates. In: Stouder DJ, Fresh KL, Feller RJ (eds). Theory and Application in Fish Feeding Ecology. Aiken: University of South Carolina Pr. p 19-43.